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A Germane Prognosis Paradigm for Climate and Weather Research

Anisha P R[1] and Vijaya Babu B[2]

ABSTRACT

Predicting weather is technically and scientifically an exigent task across the globe. This requires lot of perseverance and needs huge amount of dispensation of meteorological weather data, both numerical datasets and satellite imagery. This paper presents certain methodologies based on which an efficient mechanism is proposed for weather prediction. The mechanism makes use of both satellite imagery and numerical datasets which are analyzed through data mining techniques and image processing tools. The proposed framework involves various wavelet transformation algorithms and a comparative study is made to find the efficient algorithm for the prediction purpose. Further the methodology proposed also make use of numerical data where in one of the precipitant is considered and an experimentation is carried out to analyze various other precipitant resulting in the climatic condition. Further in order to identify the duration of the said weather condition and to find the intensity in case of any climatic calamity a framework is proposed to identify the cloud intensity by making use of the historical satellite data.

Keywords: Satellite Imagery, Data Mining, Image Processing, Wavelet Transformation, Cloud Intensity.

I. INTRODUCTION

Weather and climate are not to be the same though they refer to the same cause. Weather is the condition of the atmosphere, in contrast to the same climate is the average course of weather conditions over a period of time for a particular location. The physical climate system involves the earth's atmosphere, land surfaces, and oceans, along with the snow and ice. These components interact with one another and with aspects of the earth's biosphere to determine not only the day-to-day weather, but also the long-term averages that we refer to as 'climate'.

Figure 1 represents the schematic view of the global climate system component, their process and interaction and some aspects that might change. To create the climate in a particular region or place the physical climate system includes five interactive subsystems. It includes the atmosphere, the hydrosphere comprising rivers, lakes and oceans, the cryosphere comprising ice, sea glaciers, snow on land, the biosphere having the vegetation and marine life and the lithosphere comprising of moisture and snow. The overall balance between the incoming solar energy and the radiant heat determines the earths average temperature. The crucial feature here is that the suns energy is not uniformly disturbed, in fact it is intense at the equator and weaker at the poles. This non uniformity of energy results in temperature differences like ocean currents, evaporation, precipitation which we ultimately experience as weather.

Wind, oceans and mountains are also the factors that controls the climate changes. Winds acts as a source that moistures the land. The winds from north and south of the equator converges in the tropics rising the air. This raise in air produces thunderstorm, monsoon and humidity. As the winds crosses over the mountains it raises them which further cools the air causing the moisture to condense into the clouds and rain. On the other hand Oceans prove moisture that causes rainstorms. Weather forecasting is the

[1] Research Scholar, Dept. of CSE, K L University, Guntur

[2] Professor, Dept. of CSE, K L University, Guntur

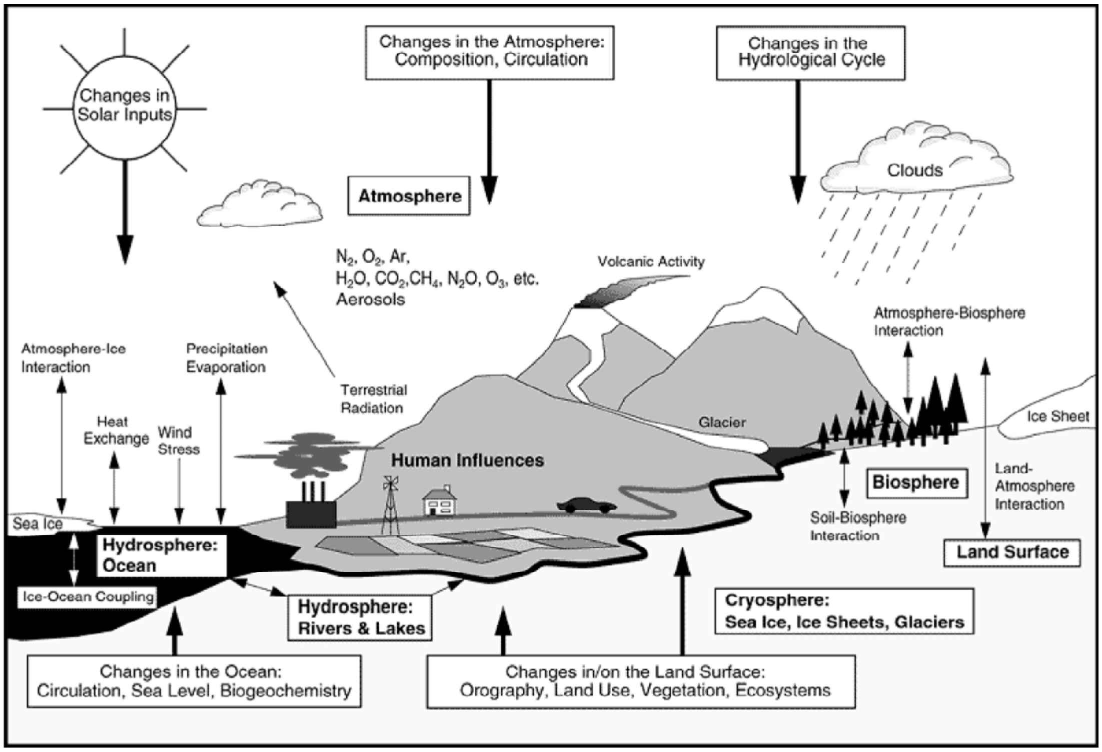

Figure 1: Schematic view of the global Climate system

attempt by meteorologists to predict the state of the atmosphere at some future time and the weather conditions that may be expected. An accurate forecast of weather tell a farmer the best time to crop his field, a safe movements of aircrafts, fisherman about the safety for their fishing, people living in coastal regions if any possibility of hurricanes.

Humans have been looking for ways to forecast the weather for centuries. Scientifically-based weather forecasting was not possible until meteorologists were able to collect data about current weather conditions from a relatively widespread system of observing stations and organize that data in a timely fashion. For viewing large weather systems on a worldwide scale, weather satellites are invaluable. Satellites show cloud formations, large weather events such as hurricanes, and other global weather systems. With satellites, forecasters can see weather across the whole globe: the oceans, continents, and poles. Recent satellite data is very detailed, even to the point of showing states and countries.

II. SCIENCE MOTIVATION

Forecasting has been one of the most scientifically and technologically challenging problems around the world in the last century. This is basically because of two factors first, its used for many human activities and secondly due to the opportunism created by various technological advances that are directly related to this concrete research field, like the evolution of computation and the improvement in measurement system.

Spatial data has many features distinguishing it from relational databases. IT carries topological and /or distance information usually organized by sophisticated multidimensional spatial indexing structures accessed by spatial indexing structures by spatial data access methods and often requiring spatial reasoning, geometric computation and spatial knowledge representation techniques. Thus spatial data mining demands an integration of data mining with spatial technologies. Though meteorologist dedicate to making accurate weather forecasts with advanced computational technologies, the long term prediction of any weather condition is not still sufficiently reliable and accurate. Due to non linear and chaotic nature of numerical models, some tiny noises in the initial values can result in large differences in the prediction. This is commonly known as the butterfly effect. Amidst all the hurdles of data processing various researchers put forth their exotic contribution towards weather prediction.

Kannan M et al. [1], in their paper presented a work of forecasting rainfall using Data Mining Techniques in which regression and multiple regression technique is used on numerical data and based on which the possibility of rainfall is forecasted. Jyosthna Devi et al. [2], presented an Artificial neural network model in which back propagation algorithm was made use over the weather datasets and are processed through various neural network propagation algorithms and the kind of precipitate was predicted.

Piyush Kapoor et al. [3], presented an article in which a statistical model is designed that could predict the rainfall and temperature with the help of past data by making use of time-delayed feed forward neural network by making use of sliding window algorithm. Amanullah et al.[4], presented a research article where in the applications of soft computing are implemented over weather prediction and based on which the analyzes is been made to forecast weather.Sangari R.S et al.[5], in their paper presented a technique of predicting rainfall by making use of various data mining technique like KNN, Decision Tree, Neural Network, Fuzzy logic, Naïve bayes. Among all the said algorithm it is found that Naïve bayes algorithm works more efficient for the weather prediction.

Y. Radhika and M. Shashi [6], in their research work presented the Atmospheric Temperature for which data mining technique Support Vector Machine is used. The support vector regression was used to predict the maximum temperature at a location. Further Mean Square Error is taken as a performance measure for accurate prediction. Jyothis Joseph and Rathesh T.K [7], in their work predicted the occurrence of rainfall. The rainfall values are clustered into substractive clustering and the rainfall identified as low, medium, heavy and given as outputs for training. Further 80% of the clustered data is taken as training set and the rest as the testing set and based on the same the weather condition is prediction.

Rajnikanth T.V et al. [8], worked out in their research work to predict weather by making use of weather datasets. On the data gather K-means cluster algorithm is applied for grouping similar data sets together and also applied J48 classification technique along with linear regression analysis. Kavirasu et al. [9], in their research work made use of image processing for the prediction of rainfall where in digital satellite images were used for this purpose. Cloud mask algorithm is used to find the cloud status and k Means clustering algorithm is been used for the prediction purpose. Moonesha and Sairam [10], in their research work presented a comparative studies by various algorithm for weather prediction upon thin clouds. Cloud images were been used for this purpose. The extract values from the cloud image are measured using Gaussian Filter. The results thus generated presented that thin clouds were more efficient for weather prediction.

Yaiprasert. C et al. [11], presented a research work in which satellite images from GOES- 9 satellite are collected of which the pixel values for the images are collected. Further a data process is designed to enable the inference of correlations between pixel values and rainfall occurrence. Based on the analysis the rainfall and its intensity of a given area is predicted. A research was conducted by Meera Narvekar and Prinyaca Fargose [12], for weather prediction in which several algorithms were verified among with neural network algorithms were used for prediction purpose. The technique uses 28 input parameters to forecast the daily weather in terms of temperature, rainfall, humidity, cloud condition, and weather of the day so as to predict the future weather conditions. R Lee et al. [13], proposed an innovative, intelligent, multi-agent based environment named as intelligent Java Agent Development Environment (iJADE). It is used for weather prediction of eleven weather stations in Hong Kong using five years data which provides more than 7300 data records. The model uses GA for input node selection, a fuzzy classification for rainfall parameters and neural network for training using a BPN. Its experimental results are more promising than single point sources using similar network and other networks like Radial Basis Function Network, Learning Vector Quantization and Naive Bayesian Network. Authors compare ANN with RBF, LVQ and Naive Bayesian Network and prove that ANN results are better as compared to others.

Yamin Wang et al. [14], proposes a novel wind speed forecasting method based on ensemble empirical mode decomposition (EEMD) and Genetic algorithm – back propagation Neural network.

Data mining consists of evolving set of techniques that can be used to extract valuable information and knowledge from massive volumes of data. The field of data mining has evolved from its roots in database, statistical artificial intelligence, information theory and algorithms into a core set of techniques that have been applied to a range of problems. The research on spatial databases mainly focuses on spatial data modeling, spatial data access, spatial data query processing, spatial data visualization and spatial data mining. The spatial data not just includes numerical datasets but they even include satellite images which act equally pre-dominant . Information obtained from various various satellite data has the potential of leading to greater understanding of convective and other mesoscale activity and also the potential of being an important component in the detection of various weather connections.

Eventually image processing and data mining would be considered to be an effective and efficient platform for weather prediction. The paper is organized with section 3 elucidates an overall process framework in brief yet an explanatory way. Further it is followed by section 4 that concludes the architecture and references as section 5.

III. PROCESS FRAMEWORK

Weather for future is one of the most important attributes to forecast because agriculture sectors as well as many industries are largely dependent on the weather conditions. Weather conditions are required to be predicted not only for future planning in agriculture and industries but also in many other fields like defense, mountaineering, shipping and aerospace navigation etc. It is often used to warn about natural disasters are caused by abrupt change in climatic conditions.

Major research and development effort is ongoing in improving all areas of the process, from development of better observational techniques (both surface systems, upper air systems, and satellite systems), development of forecasting techniques to be used by forecasters, to development of better mathematical equations and computer models, to procedures to communicate weather information to users in a timely and reliable manner. Weather prediction deals with the application of science and technology to predict the state of the atmosphere for a future time and a given location. Weather warnings are an important forecast because they are used to protect life and environment. There is a variety of methods to weather forecast.

A touchstone of scientific knowledge and understanding is the ability to predict accurately the outcome of an experiment. In meteorology, this translates into the accuracy of the weather forecast[16]. Clearly the success has required technological acumen as well as scientific advances and vision. The different ways of weather forecasting are presented as follows:

The current research work presents certain weather prediction methodologies that results in predicting the kind of precipitant not just based numerical data available but also based on the satellite data. The methodologies put forth a mechanism where in the satellite data and the surface based gauge are taken into considered for analysis, resulting with the kind of precipitant is predicted. Figure 3 presents a blueprint of the overall architecture for methodologies that are planned for the prediction of the weather precipitate.

METHODOLOGY 1 - Prediction using satellite imagery

Remote Sensing is a technique for collecting image or other forms of data about an object form measurements made at a distance from the object and the processing and analysis of the data. In other words it is the art of acquiring information(spectral, spatial, temporal) about material objects, area, or phenomenon, without coming into physical contact with the objects, area, or phenomenon under investigation. It is composed of three parts, the targets- objects, or phenomenon in an area; the data acquisition- through certain instruments

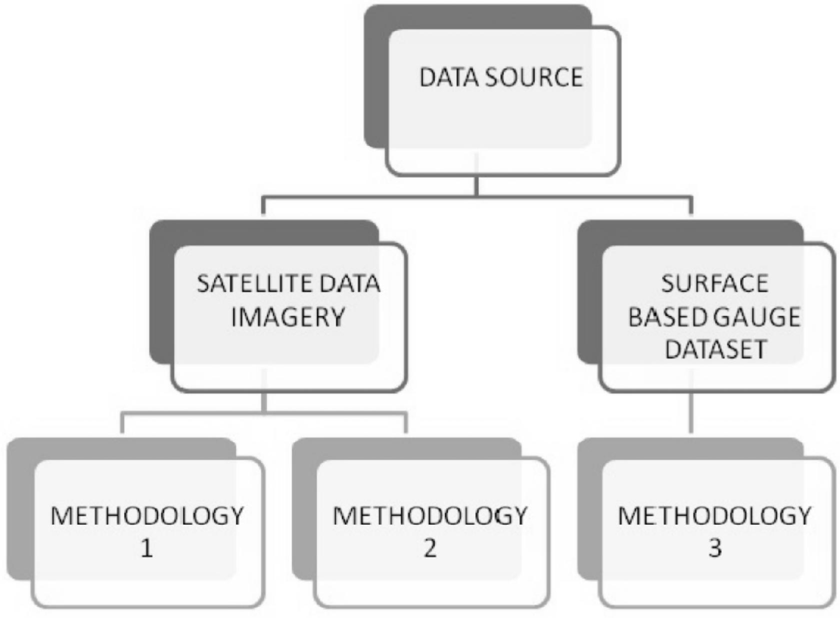

Figure 3: Precipitant Prediction Schema

and the data analysis- again by some devices. It refers to imagery and image information derived by both airborne and satellite platforms that house senor equipment. The data collected by the sensors are in the form of electromagnetic theory (EM).

Electromagnetic energy is the energy emitted, absorbed, or reflected by objects. Image processing of remotely sensed satellite or digital data refers to the management of digital database, including the display, analysis, and manipulation of digital image computer files. Most of these processes rely on concepts of geography, physical sciences and analytical statistics. Figure 4 represents the procedure that is used for the prediction of the weather precipitate using the satellite imagery which is processed through k- Means clustering technique and based on the threshold value the form of precipitate is predicted. Satellite images have been used extensively to study temporal changes. Information and knowledge of varied weather condition, their forecast and the collection of large amounts of satellite data with high spatial and temporal resolutions is indispensable[15]. In order to have a clear study of the gathered satellite images the following steps are involved.

Segmentation: Image segmentation is a mid-level processing technique used to analyze the image and can be defined as a processing technique used to classify or cluster an image into several disjoint parts by grouping the pixels to form a region of homogeneity based on the pixel characteristics like gray level, color, texture, intensity and other features. The main purpose of the segmentation process is to get more information in the region of interest in an image which helps in annotation of the object scene. Image segmentation aims at domain-independent partition of the image into a set of visually distinct and homogeneous regions with respect to certain properties. The main goal of segmentation is to clearly differentiate the object and the background in an image. If R represents an image, then the image segmentation is simply division of R into sub regions R1, R2…..Rn , such that and is governed by following set of rules: a) Ri is a connected set, i = 1,2,…..n. b) $Ri \cap Rj = Ø$ for all i and j, $i \neq j$ c) Q(Ri) = True for i= 1,2,…n. d) Q(Ri U Rj) = False for adjoint regions, Ri and Rj Where Q(Rk) is a logical predicate[42]. The rules described above mentions about continuity, one-to-one relationship, homogeneity and non-repeatability of the pixels after segmentation respectively. There are many knowledge based approaches to segment an image and can be listed as 1. Intensity based methods 2. Discontinuity based methods 3. Similarity based methods 4. Clustering methods 5. Graph based methods 6. Pixon based methods 7. Hybrid methods.

The one used here is clustering method of image segmentation. The said process includes k – means clustering technique.

k- Means clustering: Given a data set of workload samples, a desired number of clusters, *k*, and a set of *k* initial starting points, the k-means clustering algorithm finds the desired number of distinct clusters and their centroids. A centroid is defined as the point whose coordinates are obtained by computing the average of each of the coordinates (i.e., feature values) of the points of the jobs assigned to the cluster. Formally, the k-means clustering algorithm follows the following steps.

1. Choose a number of desired clusters, *k*.
2. Choose *k* starting points to be used as initial estimates of the cluster centroids. These are the initial starting values.
3. Examine each point (i.e., job) in the workload data set and assign it to the cluster whose centroid is nearest to it.
4. When each point is assigned to a cluster, recalculate the new *k* centroids.
5. Repeat steps 3 and 4 until no point changes its cluster assignment, or until a maximum number of passes through the data set is performed.

Like other clustering algorithms, k-means requires that a distance metric between points be defined [2]. This distance metric is used in step 3 of the algorithm given above. A common distance metric is the Euclidean distance. Given two sample points, p_i and p_j, each described by their feature vectors, $p_i = (F_{i1}, F_{i2}, \ldots, F_{iM})$ and $p_j = (F_{j1}, F_{j2}, \ldots, F_{jM})$, the distance, d_{ij}, between p_i and p_j is given by:

$$d_{ij} = \sqrt{\sum_{m=1}^{M} (F_{im} - F_{jm})^2} \quad (1)$$

Wavelet Transform: Wavelet analysis is an exciting new method for solving difficult problems in mathematics, physics, and engineering, with modern applications as diverse as wave propagation, data compression, signal processing, image processing, pattern recognition, computer graphics, the detection of aircraft and submarines and other medical image technology. There are many different forms of data compression. This investigation will concentrate on transform coding and then more specifically on Wavelet Transforms. Image data can be represented by coefficients of discrete image transforms. Coefficients that make only small contributions to the information contents can be omitted. Usually the image is split into blocks (sub images) of 8x8 or 16x16 pixels, then each block is transformed separately. However this does not take into account any correlation between blocks, and creates “blocking artifacts” , which are not good if a smooth image is required. However wavelets transform is applied to entire images, rather than sub images, so it produces no blocking artifacts. This is a major advantage of wavelet compression over other transform compression methods. Thresholding in Wavelet Compression For some signals, many of the wavelet coefficients are close to or equal to zero. Thresholding can modify the coefficients to produce more zeros. In Hard thresholding any coefficient below a threshold ë, is set to zero. This should then produce many consecutive zero’s which can be stored in much less space, and transmitted more quickly by using entropy coding compression.

HAAR wavelet Transform: The Haar Transform (HT) is one of the simplest and basic transformations from the space domain to a local frequency domain. A HT decomposes each signal into two components, one is called average (approximation) or trend and the other is known as difference (detail) or fluctuation. Data compression in multimedia applications has become more vital lately where compression methods are being rapidly developed to compress large data files such as images. Efficient methods usually succeed in compressing images, while retaining high image quality and marginal reduction in image size. Figure 4 represents the schematic view of the experimentation that is carried out which represents the segmentation process of the images. The satellite images are then clustered using k- Means clustering techniques according

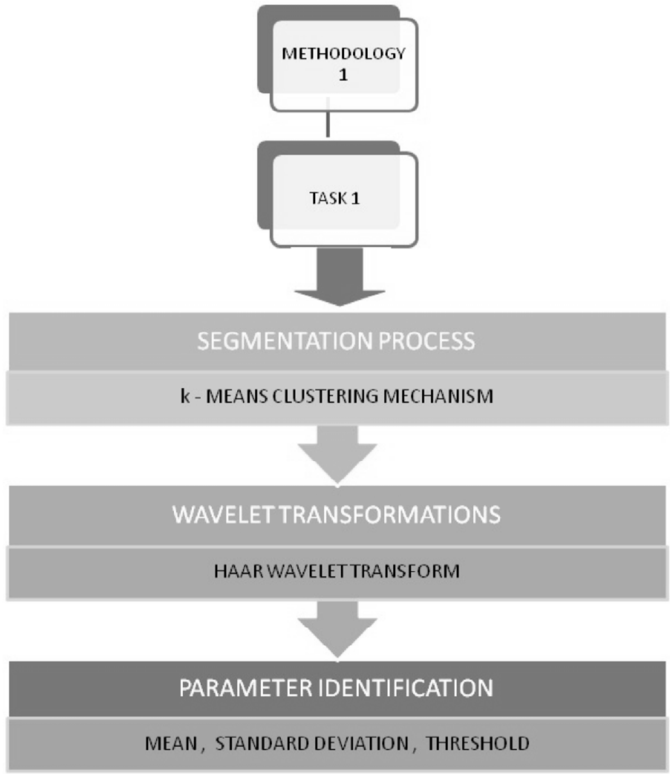

Figure 4: Prediction using Haar wavelet

to the steps mentioned above. Haar wavelet transform is applied over the images on the basis of which parameters such as mean,standard deviation and threshold values are identified.

Figure 5 represents the bird eye view of the experimentation that is carried out using Daubechies wavelet transform. Daubechies Wavelet transforms are multi-resolution image decomposition tool that provide a

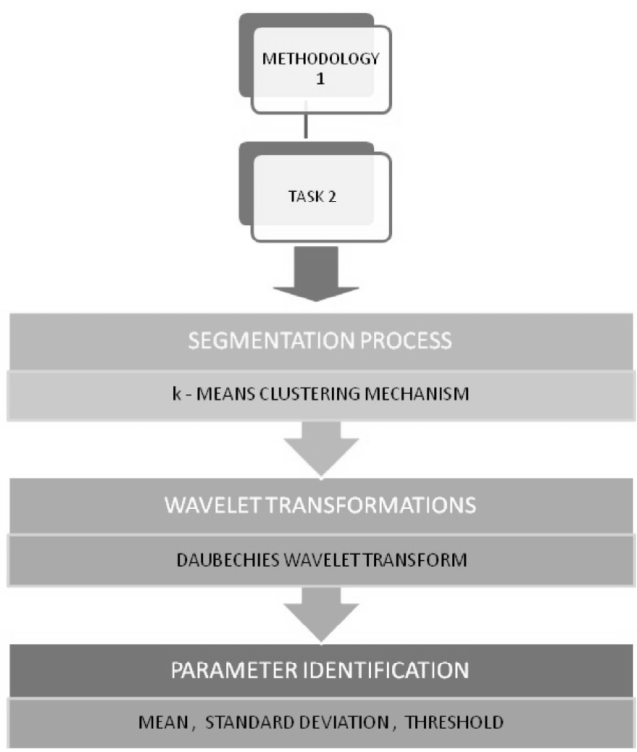

Figure 5: Prediction using daubechies wavelet

variety of channels representing the image feature by different frequency sub bands at multi-scale. The Ingrid Daubechies, one of the brightest stars in the world of wavelet research, invented what are called compactly supported orthonormal wavelets — thus making discrete wavelet analysis practicable. The names of the Daubechies family wavelets are written dbN, where N is the order, and db the "surname" of the wavelet. The db1 wavelet is the same as Haar wavelet. Daubechies wavelets are a family of orthogonal wavelets defining a discrete wavelet transform and characterized by a maximal number of vanishing moments for some given support. This kind of 2D DWT aims to decompose the image into approximation coefficients (cA) and detailed coefficient cH, cV and cD (horizontal, vertical and diagonal) obtained by wavelet decomposition of the input image (X).

Figure 6 is a schematic experimentation process that process the satellite images to obtain the final parameters using Coif wavelet transform. Coiflets was originally derived from the Daubechies wavelet. It has an even higher computational overhead and uses windows that overlap more. it uses six scaling and wavelet function coefficients, so increase in pixel averaging and differencing leads to a smoother wavelet and increased capabilities in several image-processing techniques (de-noising images, etc.). The filter follows the same structure as both Haar and Daubechies. It calculates both averages and differences using the same format, only with six adjacent pixels. The Coiflet wavelet also follows the mirror technique. (From Wavelet-based Texture Classification of Tissues in Computed Tomography) The wavelet function has 2N moments equal to 0 and the scaling function has 2N-1 moments equal to 0. The two functions have a support of length 6N-1. General characteristics:

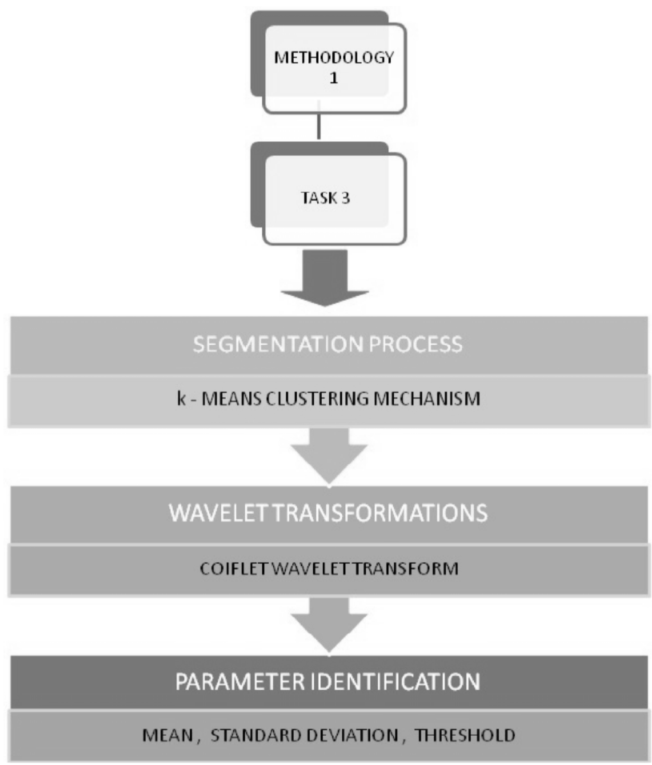

Figure 6 : Prediction using Coiflet wavelet transform

Figure 7 and Figure 8 is the framework for bi-orthogonal wavelet transform and RBIO wavelet transform that is used for the parameter identification on dispensation of the satellite images respectively. In the biorthogonal case, rather than having one scaling and wavelet function, there are two scaling functions φ, φe, that may generate different multiresolution analysis, and accordingly two different wavelet functions ψ, ψe. ψe is used in the analysis and ø is used in the synthesis. In addition, the scaling functions φ, φe and the wavelet functions ψ, ψe are related by duality in the following sense

$$\int \psi j,k(x)\psi e'j,k'(x)dx = 0$$

as soon as j 6= ´j or k 6= ´k and even.

$$\int \varphi 0,k(x)\,\varphi e\,0,k'(x)\,dx = 0$$

as soon as k 6= ´k.

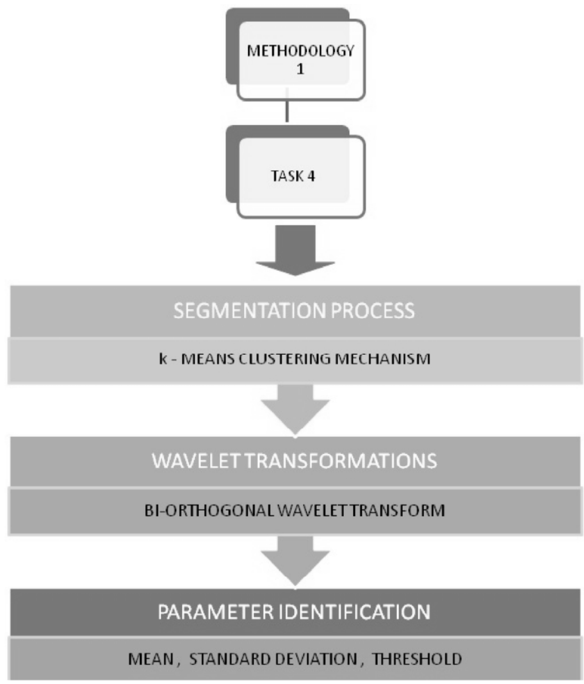

Figure 7: Prediction using Biorthogonal wavelet transform

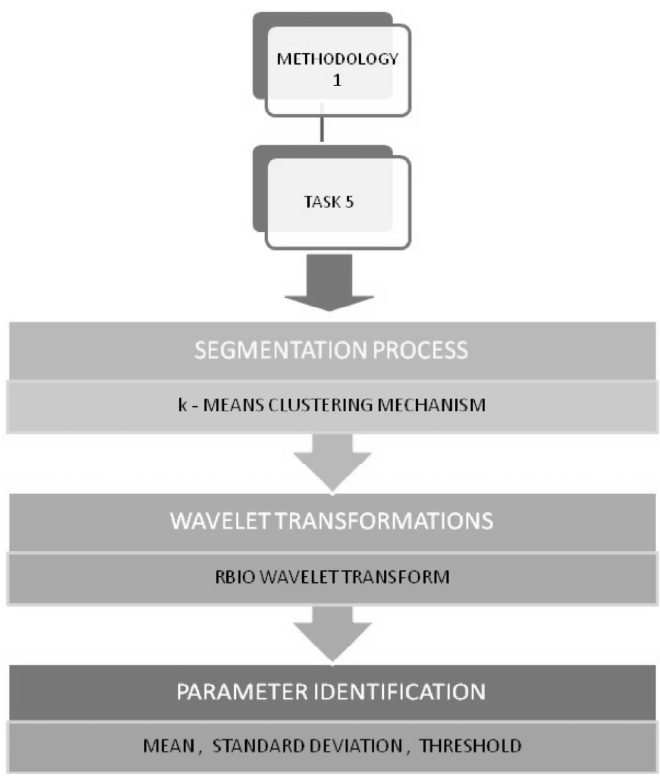

Figure 8: Prediction using Rbio wavelet transform

METHODOLOGY 2 – Prediction using Surface based gauged data

Climate change is a significant and lasting change in the statistical distribution of weather patterns over periods ranging from decades to millions of years. It may be a change in average weather conditions or the distribution of events around that average (e.g., more or fewer extreme weather events). The term is sometimes used to refer specifically to climate change caused by human activity, as opposed to changes in climate that may have resulted as part of Earth's natural processes. Climate change today is synonymous with anthropogenic global warming. Within scientific journals, however, global warming refers to surface temperature increases, while climate change includes global warming and everything else that increasing greenhouse gas amounts will affect.

Evidence for climatic change is taken from a variety of sources that can be used to reconstruct past climates. Reasonably complete global records of surface temperature are available beginning from the mid-late 19th century. For earlier periods, most of the evidence is indirect. Climatic changes are inferred from changes in proxies, indicators that reflect climate, such as vegetation, ice cores, dendrochronology, sea level change, and glacial geology. To predict the weather by numerical means, meteorologists have developed atmospheric models that approximate the atmosphere by using mathematical equations to describe how atmospheric temperature, pressure, and moisture will change over time.

The equations are programmed into a computer and data on the present atmospheric conditions are fed into the computer. The computer solves the equations to determine how the different atmospheric variables will change over the next few minutes. The computer repeats this procedure again and again using the output from one cycle as the input for the next cycle. Climate is the long-term effect of the sun's radiation on the rotating earth's varied surface and atmosphere. The Day-by-day variations in a given area constitute the weather, whereas climate is the long term synthesis of such variations. Weather is measured by thermometers, rain gauges, barometers, and other instruments, but the study of climate relies on statistics. Nowadays, such statistics are handled efficiently by computers. The evolution of weather science as well as of high-performance computing and observing systems in the future is crucial for continuing the progress in NWP. In the present methodology the surface based gauged data is considered of which the system is programmed such that the data fed would be processed resulting in representing the other weather parameters.

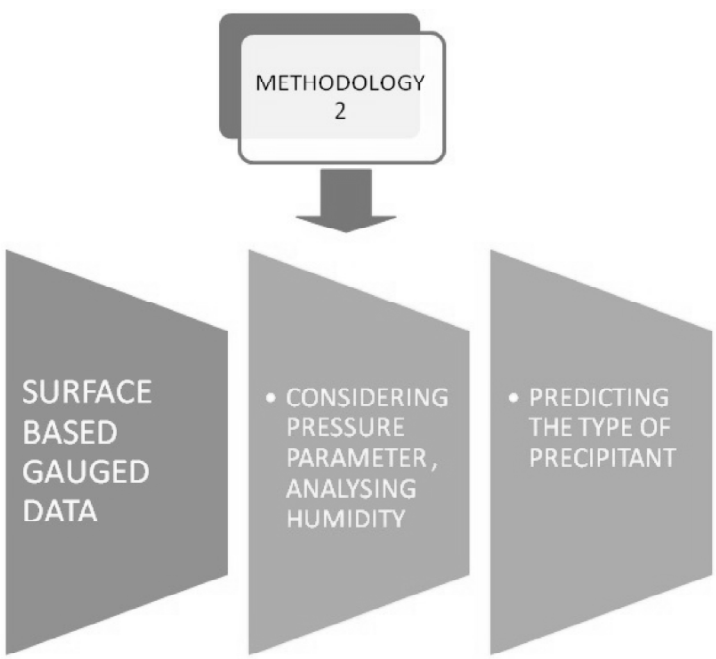

Figure 9: Analysis of precipitant through surface based data

The weather parameters hence gained is processed further through the system program in order to predict the kind of precipitant that would be formed. The resulting precipitant is compared with the historical data sets and it is further contemplated with the historical data to analyze the amount of accuracy that the system has attained for prediction.

METHODOLOGY 3 – Analysis of the precipitate based on the Cloud Intensity

A wide variety of cameras, instruments and sensors are installed in satellites currently orbiting the earth. The data provided from these sources are of great use to surf forecasters. The payloads provide nearly live coverage of weather events around the globe. They capture images of land, sea and clouds, measure wave heights, sea temperature and elevations, wind speed and direction. Each piece of data contributes to developing an overall assessment of global weather and surf generation potential. There are three main types of satellite images available:

VISIBLE IMAGERY: Visible satellite pictures can only be viewed during the day, since clouds reflect the light from the sun. On these images, clouds show up as white, the ground is normally grey, and water is dark. In winter, snow-covered ground will be white, which can make distinguishing clouds more difficult. To help differentiate between clouds and snow, looping pictures can be helpful; clouds will move while the snow won't. Snow-covered ground can also be identified by looking for terrain features, such as rivers or lakes. Rivers will remain dark in the imagery as long as they are not frozen. If the rivers are not visible, they are probably covered with clouds. Visible imagery is also very useful for seeing thunderstorm clouds building. Satellite will see the developing thunderstorms in their earliest stages, before they are detected on radar.

INFRARED IMAGERY: Infrared satellite pictures show clouds in both day and night. Instead of using sunlight to reflect off of clouds, the clouds are identified by satellite sensors that measure heat radiating off of them. The sensors also measure heat radiating off the surface of the earth. Clouds will be colder than land and water, so they are easily identified. Infrared imagery is useful for determining thunderstorm intensity. Strong to severe thunderstorms will normally have very cold tops. Infrared imagery can also be used for identifying fog and low clouds. The fog product combines two different infrared channels to see fog and low clouds at night, which show up as dark areas on the imagery.

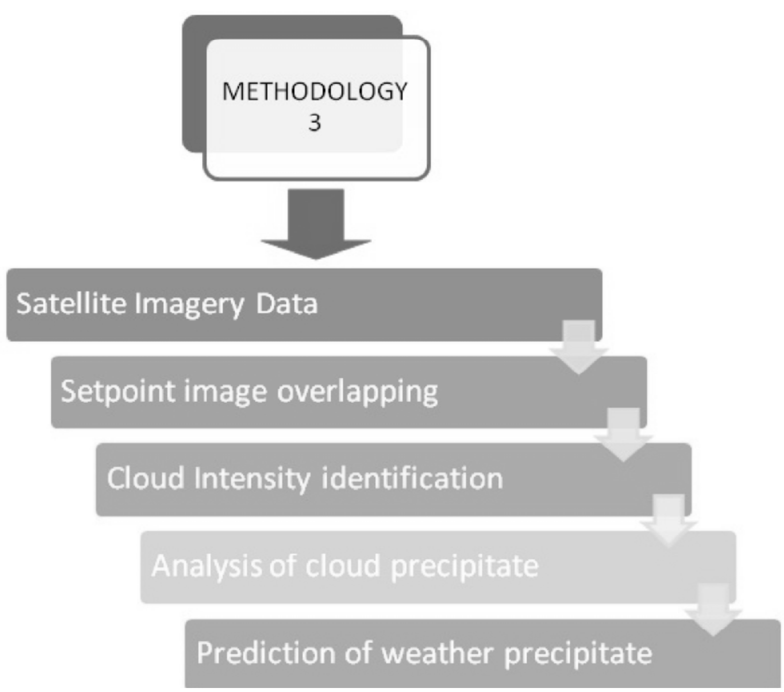

Figure 10: Prediction of the intensity of the cloud for a precipitant

WATER VAPOR IMAGERY: Water vapor satellite pictures indicate how much moisture is present in the upper atmosphere (approximately from 15,000 ft to 30,000 ft). The highest humidities will be the whitest areas while dry regions will be dark. Water vapor imagery is useful for indicating where heavy rain is possible. Thunderstorms can also erupt under the high moisture plumes.

The following methodology presents a procedure where in satellite imagery that are processed earlier for identifying the kind of precipitants is currently used to identify the intensity of the precipitant. The following procedure is implement such that the satellite images gather are process using the classifiers and the resulted image hence generated are gathered and based on the season, date and time the classified images are gathered. The images are further organized to a hypothetical set points based on the n times experimentation. Thus the set points fixed are taken into account using which the image overlapping is carried out for which MATLAB is used as an efficient tool. Based on the overlapping the ROI is considered on the basis of which the intensity of the cloud is analyzed. On analysis of the intensity of the cloud which is the region of interest here. Based on the intensity value and hypothetical calculation the kind of precipitate is predicted.

IV. CONCLUSION

In mist of various research works carried out by various research to find an efficient prediction methodology of weather this paper proposes an overall framework that includes experimentation carried out using both numerical and satellite data imagery. To attain a legitimate accuracy the said experimental results are being compared to the historical data.

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